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ADP015000

TITLE: A New Explanation of the Instability of High Intensity Discharge
Operated in High Frequency

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This paper is part of the following report:

TITLE: International Conference on Phenomena in Ionized Gases [26th]
Held in Greifswald, Germany on 15-20 July 2003. Proceedings, Volume 4

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ADP014936 thru ADP015049

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A new explanation of the instability of high intensity discharge operated in high frequency

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Abstract

Analysed the irrationality of so called "acoustic resonance" theory, that was suggested forty years ago to explain the instability of high frequency arc generated in high intensity discharge lamp. Presented a new idea that the ion oscillation in plasma is the culprit of instability of high frequency arc.

1. Introduction

The arc instability of high intensity discharge (HID) generated in high pressure lamp with high frequency operation was studied for forty years [1, 2, 3, 4, 5, 6, 7]. Researchers found that the high pressure xenon lamp and all other high pressure discharge device were unstable while it is operated in high frequency from decade KHz to few hundred KHz, they also found that a kind of acoustic wave always accompanied with instable high frequency arc and the frequency of acoustic wave is always double of discharge. The brightness and all other parameters such as current and potential drop of unstable arc were also fluctuated with a frequency around few to decade Hz, mean while the arc was curved and shivered. All researchers and papers published explain the above phenomena in a same way. All of them firmly believe the theory of so called "acoustic resonance" effect. The main points of this theory is as following:

Inside the high frequency operated discharge tube gas is heated intermittent by arc with a frequency double of discharge. Gas is heated by input current while it is positive or negative peak, but it is condensed while discharge polarity change because of zero input power, then the partial wave or said pressure wave is created. This is the reason of acoustical wave generating. If the acoustical wave is resonate with the wall of arc tube, then a standing wave forms and the discharge become unstable. The resonate frequency lower the amplitude of standing wave bigger and the discharge instability more serious. For the lowest resonate frequency that means the half of acoustic wave length is just equal to the diameter of arc tube, perhaps the arc will be extinguished or even broken the arc tube because of acoustic wave resonance. In the past forty years especially last fifteen years, the arc instability was a main barrier for developing the high frequency electronic ballast for metal halide lamps. Experts did their best to overcome the problem of so called "acoustic resonance", but not succeeded.

2. The theory of acoustic resonance is not correct

Our research find that the theory of acoustic resonance is not correct to explain the phenomenon of instability of high frequency arc.

2.1 Gas temperature can not be changed with the frequency double of arc

Inside a operating high frequency arc tube the gas temperature is from 1000K near tube wall to 6000K at the core of arc and the gas pressure is around 20 bar. As a medium with very high pressure and very high temperature the heating capacity of plasma gas is very large. It is not easy to change the temperature within a short time catch up with discharge frequency. In fact, the temperature of gas inside a operating arc tube is almost keep constant without obvious fluctuation even while discharge polarity change.

2.2 Acoustic wave is only found from the instable arc but not stable one

The acoustic wave is only found from instable arc, but never discovered from a stable arc. If according to the theory of acoustic resonance, this kind of pressure wave should be always generated from any kind of high frequency arc either stable or not because of the alternating input power. This is an evidence to prove that the acoustic wave is not caused by gas temperature fluctuation but from other sources, the temperature fluctuation of high frequency arc can be neglected even if exist.

According to the theory of acoustic resonance, the temperature fluctuation and also the amplitude of pressure wave of high frequency arc should be bigger for lower frequency discharge, but researchers did not found

this kind of wave from an arc which the frequency is below 2KHz and all arc below this frequency is always very stable. This is another evidence proving that the temperature fluctuation can be neglected .

2.3 Parameters fluctuation of instable arc is only few Hz

According to the theory of acoustic resonance, the frequency of acoustic wave is double of discharge. Usually the arc instability is only found in the frequency range from few KHz to few hundred KHz. But the fluctuation of arc brightness and other discharge parameters of an instable arc is discovered only few times per second and changes all the time. It is not found any relations between acoustic wave and brightness fluctuation from any instable arc .

3. A new explanation of instability of high frequency arc

The main points of the new explanation for high frequency arc instability we suggest are as follow:

3.1 Acoustic wave is not exist in a stable arc

No one find acoustical wave form a stable arc even it is operated in high frequency and no one find obvious temperature fluctuation from it,even it is heated by high frequency input power.

Even acoustic wave radiate from an unstable arc, but it still is not found temperature fluctuation with the frequency double of discharge.

3.2 Instability of high frequency arc is caused by plasma oscillation

Plasma oscillation is the source of acoustical wave and causes arc instable. For a DC discharge or a discharge the frequency below 2KHz the plasma oscillation is a random process, it attenuated very fast because of collisions with atoms [8] .But for high frequency discharge the ion oscillations will respond with field and amplified by it, if the frequency of ion oscillation is resonant with field ,then a stable ion oscillation appear. The frequency of ion oscillation is just equal to the field frequency inside discharge. The huge number of ions oscillated together and accompanied by huge number of atoms because of momentum transfer by collisions between them must create a pressure wave .This is the acoustic wave found for forty years, and it is only a product of ion oscillation could be found from instable arc but not the culprit of arc instability.

Ion oscillation is the culprit which causes arc instable. In a arc ions and electron will separated because of ion

oscillation, then the different part of the arc will charged to different polarity , the force between the different parts of the arc and the wall of tube lost balance , the path of arc will be curved and shivered because of the positive part and negative parts of arc shift in the space. This is the reason which causes discharge parameters and brightness fluctuation.

3.3 Ion oscillation creates acoustical wave

Obversly,the acoustical wave is created by ion oscillation but not temperature fluctuation. This is the reason why it is only found from an unstable plasma ,but not stable arc.

4 . Conclusion

Arc instability of high frequency discharge can not be explained by the so called "Acoustic Resonance" theory. But it is very easy described by the idea of ion oscillation, and also some experiments about arc instability are matched with the theory of ion oscillation very well. The only way to overcome the difficulty of arc instability is to control the process of ion oscillation,but not the resonant conditions between acoustic wave and arc tube shape.

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